

# Wireless Transfer of Electricity in Outer Space\*

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## Abstract

Author offers conclusions from his research of a revolutionary new idea - transferring electric energy in the hard vacuum of outer space wirelessly, using a plasma power cord as an electric cable (wire). He shows that a certain minimal electric current creates a compressed force that supports the plasma cable in the compacted form. A large energy can be transferred hundreds of millions of kilometers by this method. The required mass of the plasma cable is only hundreds of grams. He computed the macroprojects: transference of hundreds kilowatts of energy to Earth's Space Station, transferring energy to the Moon or back, transferring energy to a spaceship at distance 100 million of kilometers, the transfer energy to Mars when one is located at opposed side of the distant Sun, transfer colossal energy from one of Earth's continents to another continent (for example, between Europe-USA) wirelessly—using Earth's ionosphere as cable, using Earth as gigantic storage of electric energy, using the plasma ring as huge MagSail for moving of spaceships. He also demonstrates that electric current in a plasma cord can accelerate or brake spacecraft and space apparatus.

**Key words:** transferring of electricity in space; transfer of electricity to spaceship, Moon, Mars; plasma MagSail; electricity storage; ionosphere transfer of electricity.

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\*Presented to 45th AIAA Aerospace Science Meeting, 8 - 11 January 2007, Reno, Nevada, USA.

## Introduction

The production, storage, and transference of large amounts of electric energy is an enormous problem for humanity, especially of energy transfer in outer space (vacuum). These spheres of industry are search for, and badly need revolutionary ideas. If in production of energy, space launch and flight we have new ideas (see [1]-[16]), it is not revolutionary ideas in transferring and storage energy except the work [4].

However, if we solve the problem of transferring energy in outer space, then we solve the many problems of manned and unmanned space flight. For example, spaceships can move long distances by using efficient electric engines, orbiting satellites can operate unlimited time periods without entry to Earth's atmosphere, communication satellites can transfer a strong signal directly to customers, the International Space Station's users can conduct many practical experiments and the global space industry can produce new materials. In the future, Moon and Mars outposts can better exploration the celestial bodies on which they are placed at considerable expense.

Other important Earth mega-problem is efficient transfer of electric energy long distances (intra-national, international, intercontinental). The consumption of electric energy strongly depends on time (day or night), weather (hot or cold), from season (summer or winter). But electric station can operate most efficiently in a permanent base-load generation regime. We need to transfer the energy a far distance to any region that requires a supply in any given moment or in the special hydro-accumulator stations. Nowadays, a lot of loss occurs from such energy transformation. One solution for this macro-problem is to transfer energy from Europe to the USA during nighttime in Europe and from the USA to Europe when it is night in the USA. Another solution is efficient energy storage, which allows people the option to save electric energy.

The storage of a big electric energy can help to solve the problem of cheap space launch. The problem of an acceleration of a spaceship can be solved by use of a new linear electrostatic engine suggested in [5]. However, the cheap cable space launch offered by author [4] requires use of gigantic energy in short time period. (It is inevitable for any launch method because we must accelerate big masses to the

very high speed -  $8 \div 11$  km/s). But it is impossible to turn off whole state and connect all electric station to one customer. The offered electric energy storage can help solving this mega-problem for humanity.

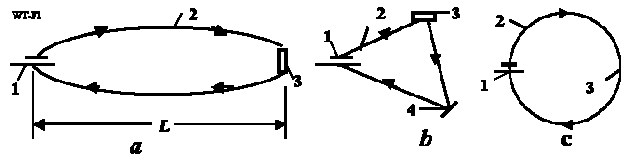
### Offered Innovations and Brief Descriptions

The author offers the series of innovations that may solve the many macro-problems of transportation energy in space, and the transportation and storage energy within Earth's biosphere. Below are some of them.

- 1) transfer of electrical energy in outer space using the conductive cord from plasma. Author solved the main problem - how to keep plasma cord in compressed form. He developed theory of space electric transference, made computations that show the possibility of realization for these ideas with existing technology. The electric energy may be transferred in hundreds millions of kilometers in space (include Moon and Mars).
- 2) method of construction for space electric lines and electric devices.
- 3) method of utilization of the plasma cable electric energy.
- 4) a new very perspective gigantic plasma MagSail for use in outer space as well as a new method for connection the plasma MagSail to spaceship.
- 5) a new method of projecting a big electric energy through the Earth's ionosphere.
- 6) a new method for storage of a big electric energy used Earth as a gigantic spherical condenser.
- 7) a new propulsion system used longitudinal (cable axis) force of electric currency.

Below are some succinct descriptions of some constructions made possible by these revolutionary ideas.

**1. Transferring electric energy in Space.** The electric source (generator, station) is connected to a space apparatus, space station or other planet by two artificial rare plasma cables (Fig.1a). These cables can be created by plasma beam [7] sent from the space station or other apparatus.



**Fig.1.** Long distance plasma transfer electric energy in outer space. *a* - Parallel plasma transfer, *b* - Triangle plasma transfer, *c* - circle plasma transfer. Notations: 1 - current source (generator), 2 - plasma wire (cable), 3 - spaceship, orbital station or other energy addresses, 4 - plasma reflector.

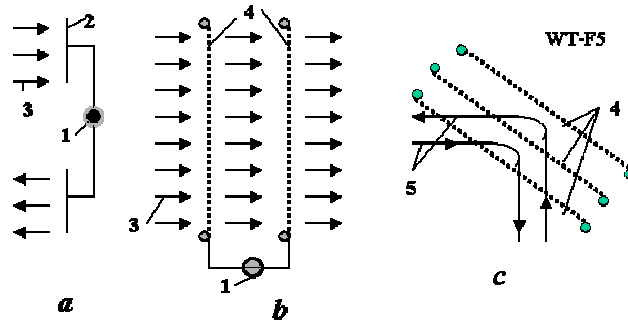
The plasma beam may be also made the space apparatus from an ultra-cold plasma [7] when apparatus starting from the source or a special rocket. The plasma cable is self-supported in cable form by magnetic field created by electric currency in plasma cable because the magnetic field produces a magnetic pressure opposed to a gas dynamic plasma pressure (teta-pinch)(Fig. 2). The plasma has a good conductivity (equal silver and more) and the plasma cable can have a very big cross-section area (up thousands of square meter). The plasma conductivity does not depend on its density. That way the plasma cable has a no large resistance although the length of plasma cable is hundreds millions of kilometers. The needed minimum electric currency from parameters of a plasma cable researched in theoretical section of this article.



**Fig.2.** A plasma cable supported by self-magnetic field. Notations: 1 -plasma cable, 2 - compressing magnetic field, 3 - electric source, 4 - electric receiver, 5 - electric currency, 6 - back plasma line.

The parallel cables having opposed currency repels one from other (Fig.1a). They also can be separated by a special plasma reflector as it shown in figs. 1b, 2c. The electric cable of the plasma transfer can be made circular (Fig. 1c). The radial compressed magnetic force from a circle currency may be balanced a small rotation of the plasma cable (see theoretical section). The circle form is comfortable for building the big plasma cable lines for spaceship not having equipment for building own electric lines or before a space launch. We build small circle and gradually increase the diameter up to requisite value (or up spaceship). The spaceship connects to line in suitable point. Change the diameter and direction of plasma circle we support the energy of space apparatus. At any time the spaceship can disconnect from line and circle line can exist without user.

The electric tension (voltage) in a plasma cable is made two nets in issue electric station (electric generator) [7]-[8]. The author offers two methods for extraction of energy from the electric cable (Fig.3) by customer (energy addresses). The plasma cable currency has two flows: electrons (negative) flow and opposed ions (positive) flow in one cable. These flows create an electric current. (It may be instances when ion flow is stopped and current is transferred only the electron flow as in a solid metal or by the ions flow as in a liquid electrolyte. It may be the case when electron-ion flow is moved in same direction but electrons and ions have different speeds). In the first method the two nets create the opposed electrostatic field in plasma cable (resistance in the electric cable [7]-[8]) (figs.1, 3b). This apparatus resistance utilizes the electric energy for the spaceship or space station. In the second method the charged particles are collected a set of thin films (Fig. 3a) and emit (after utilization in apparatus) back into continued plasma cable (Fig.3a)(see also [7]-[8]).



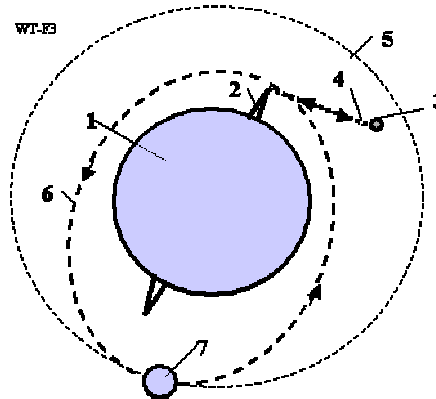
**Fig.3.** Getting the plasma currency energy from plasma cable. *a* - getting by two thin conducting films; *b* - getting two nets which brake the electric current flux; *c* - plasma reflector. Notations: 1 - spaceship or space station, 2 - set (films) for collect (emit) the charged particles, 3 - plasma cable, 4 - electrostatic nets.

Fig. 3c presents the plasma beam reflector [7]-[8]. That has three charged nets. The first and second nets reflect (for example) positive particles, the second and third nets reflected the particles having an opposed charge.

**2. Transmitting of the electric energy to satellite, Earth's Space Station, or Moon.** The suggested method can be applied for transferring of electric energy to space satellites and the Moon. For transmitting energy from Earth we need a space tower of height up 100 km, because the Earth's atmosphere will wash out the plasma cable or we must spend a lot of energy for plasma support. The design of solid, inflatable, and kinetic space towers are revealed in [4],[13]-[14],[16].

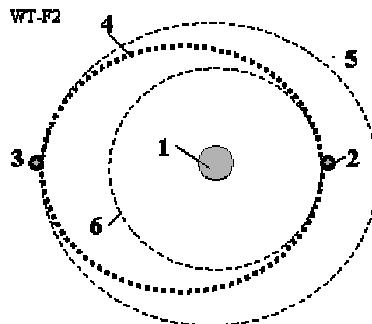
It is possible this problem may be solved with an air balloon located at 30-45 km altitude and connected by conventional wire with Earth's electric generator. Further computation can make clear this possibility.

If transferring valid for one occasion only, that can be made as the straight plasma cable 4 (Fig. 4). For multi-applications the elliptic closed-loop plasma cable 6 is better. For permanent transmission the Earth must have a minimum two space towers (Fig.4). Many solar panels can be located on Moon and Moon can transfer energy to Earth.



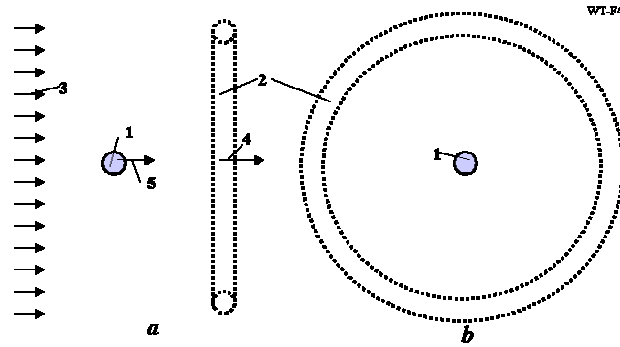
**Fig.4.** Transferring electric energy from Earth to satellite, Earth's International Space Station or to Moon (or back) by plasma cable. Notations: 1 - Earth, 2 - Earth's tower 100 km or more, 3 - satellite or Moon, 4 - plasma cable, 5 - Moon orbit, 6 - plasma cable to Moon, 7 - Moon.

**3. Transferring energy to Mars.** The offered method may be applied for transferring energy to Mars including the case when Mars may be located in opposed place of Sun (Fig. 5). The computed macroproject is in Macroprojects section.



**Fig.5.** Transferring of electric energy from Earth to Mars located in opposed side of Sun. Notations: 1 - Sun, 2 - Earth, 3 - Mars, 4 - circle plasma cable.

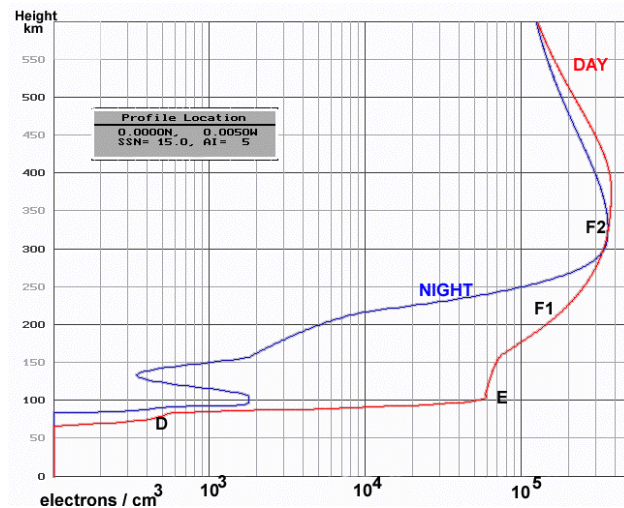
**4. Plasma AB Magnetic Sail.** Very interesting idea to build a gigantic plasma circle and use it as a Magnetic Sail (Fig. 6) harnessing the Solar Wind. The computations show (see section "Macroproject") that the electric resistance of plasma cable is small and the big magnetic energy of plasma circle is enough for existence of a working circle in some years without external support. The connection of spaceship to plasma is also very easy. The space ship create own magnetic field and attracts to MagSail circle (if spacecraft is located behind the ring) or repels from MagSail circle (if spaceship located ahead of the ring). The control (turning of plasma circle) is also relatively easy. By moving the spaceship along the circle plate, we then create the asymmetric force and turning the circle. This easy method of building the any size plasma circle was discussed above.



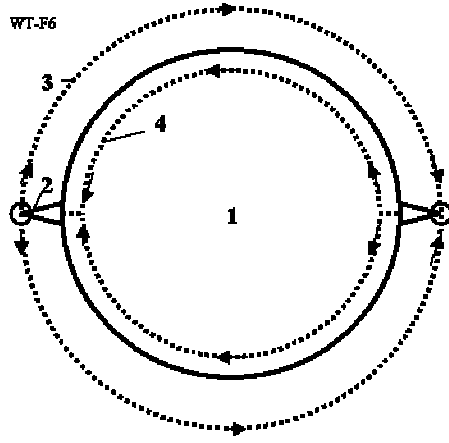
**Fig.6.** Plasma AB-MarSail. Notations: 1 - spaceship, 2 - plasma ring (circle), 3 - Solar wind, 4 - MagSail thrust, 5 - magnetic force of spaceship.

**5. Wireless transferring of electric energy in Earth.** It is interesting the idea of energy transfer from one Earth continent to another continent without wires. As it is known the resistance of infinity (very large) conducting medium does not depend from distance. That is widely using in communication. The sender and receiver are connected by only one wire, the other wire is Earth. The author offers to use the Earth's ionosphere as the second plasma cable. It is known the Earth has the first ionosphere layer *E* at altitude about 100 km (Fig. 7). The concentration of electrons in this layer reaches  $5 \times 10^4$   $1/\text{cm}^3$  in daytime and  $3.1 \times 10^3$   $1/\text{cm}^3$  at night (Fig. 7). This layer can be used as a conducting medium for transfer electric energy and communication in any point of the Earth. We need minimum two space 100 km. towers (Fig. 8). The cheap optimal inflatable, kinetic, and solid space towers are offered and researched by author in [4], [6], [7], [16]. Additional innovations are a large inflatable conducting balloon at the end of the tower and big conducting plates in a sea (ocean) that would dramatically decrease the contact resistance of the electric system and conducting medium.

Theory and computation of these ideas are presented in Macroprojects section.



**Fig.7.** Consentration/ $\text{cm}^3$  of electrons (= ions) in Earth's atmosphere in the day and night time in the D, E, F1, and F2 layers of ionosphere.



**Fig.8.** Using the ionosphere as conducting medium for transferring a huge electric energy between continents and as a large storage of the electric energy. Notations: 1 - Earth, 2 - space tower about 100 km of height, 3 - conducting  $E$  layer of Earth's ionosphere, 4 - back connection through Earth.

## Theory of space plasma transfer for electric energy, estimations and computations

**1. General theory.** The magnetic intensity and magnetic pressure of straight electric currency has maximum on surface of plasma cable. Let us to equate plasma gas pressure to a magnetic pressure and find the request equilibrium electric currency for same temperature of electrons and ions

$$P_g = 2nkT_k, \quad P_m = \frac{\mu_0 H^2}{2}, \quad H = \frac{I}{2\pi r}, \quad (1)$$

$$P_m = P_g, \quad I = 4\pi r \left( \frac{knT_k}{\mu_0} \right)^{0.5}, \quad T_k = \frac{m_e u_e^2}{2k},$$

where  $P_g$  is plasma gas pressure,  $\text{N/m}^2$ ;  $P_m$  is magnetic pressure,  $\text{N/m}^2$ ;  $n$  is plasma density,  $1/\text{m}^3$ ;  $k = 1.38 \times 10^{-23}$  is Boltzmann coefficient,  $\text{J/K}$ ;  $\mu_0 = 4\pi 10^{-7}$  is magnetic constant,  $\text{G/m}$ ;  $H$  is magnetic intensity,  $\text{A/m}$ ;  $I$  is electric currency,  $\text{A}$ ;  $r$  is radius of plasma cable,  $\text{m}$ ;  $T_k$  is plasma temperature,  $\text{K}$ ;  $m_e = 9.11 \times 10^{-31}$  is electron mass,  $\text{kg}$ ;  $u_e$  is electron speed,  $\text{m/s}$ .

From relation for the currency we have a current electron speed  $u$  relative ions along cable axis

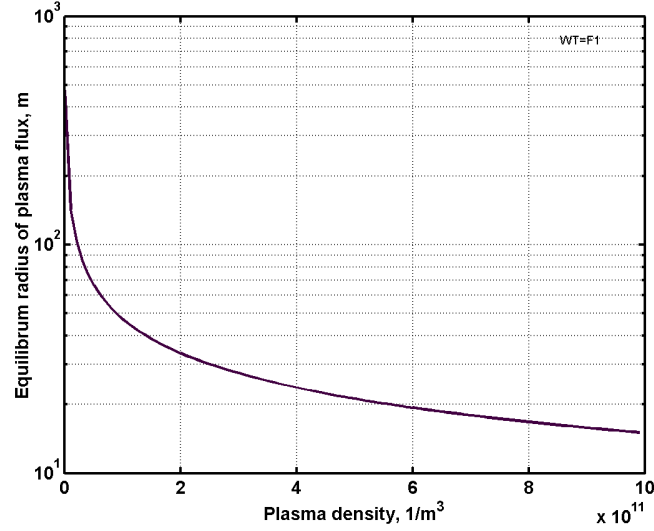
$$u = \frac{I}{enS} = \frac{4\pi r}{enS} \left( \frac{nm_e}{2\mu_0} \right)^{0.5} u_e, \quad (2)$$

where  $S = \pi r^2$  is cross-section area of plasma cable,  $\text{m}^2$ .

The mass of ion is more the mass of electron in thousands times and we assume  $u = u_e$  in (2) after some collisions. From this condition we find the relation between  $r$  and  $n$

$$r = \frac{2}{e} \sqrt{\frac{2m_e}{\mu_0}} \frac{1}{\sqrt{n}} \approx \frac{1.5 \times 10^7}{\sqrt{n}}, \quad (3)$$

The computation (2) is presented in Fig. 9.



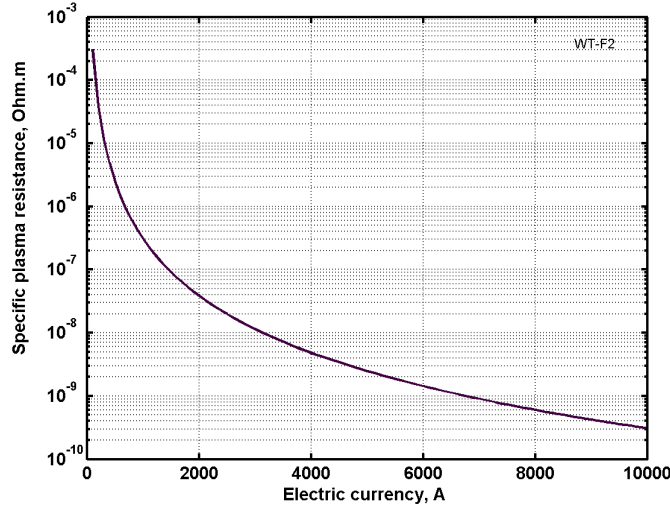
**Fig.9.** Equilibrium radius of plasma cable via plasma density.

Specific plasma resistance and usual resistance of cable can be computed by equations:

$$\rho = 1.03 \times 10^{-4} Z \ln \Lambda T^{-3/2} \Omega \text{m}, \quad R = \rho l / S, \quad (4)$$

where  $\rho$  is specific plasma resistance,  $\Omega \cdot \text{m}$ ;  $Z$  is ion charge state,  $\ln \Lambda \approx 5 \div 15 \approx 10$  is Coulomb logarithm;  $T = T_k k / e = 0.87 \times 10^{-4} T_k$  is plasma temperature in eV;  $e = 1.6 \times 10^{-19}$  is electron charge, C;  $R$  is electric resistance of plasma cable,  $\Omega$ ;  $l$  is plasma cable length, m;  $S$  is the cross-section area of the plasma cable,  $\text{m}^2$ .

The computation of specific resistance of plasma cable is presented in Fig. 10.



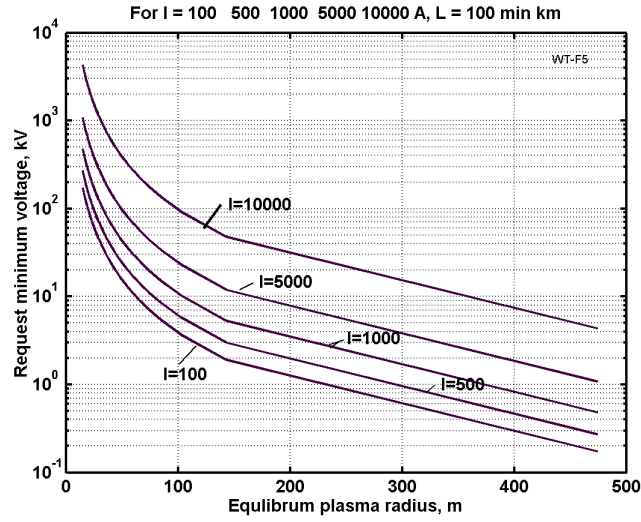
**Fig.10.** Specific plasma resistance  $\Omega \cdot \text{m}$  of equilibrium plasma cable versus electric current, A.

The requested a minimum voltage, power, the transmitter power and coefficient of electric efficiency are:

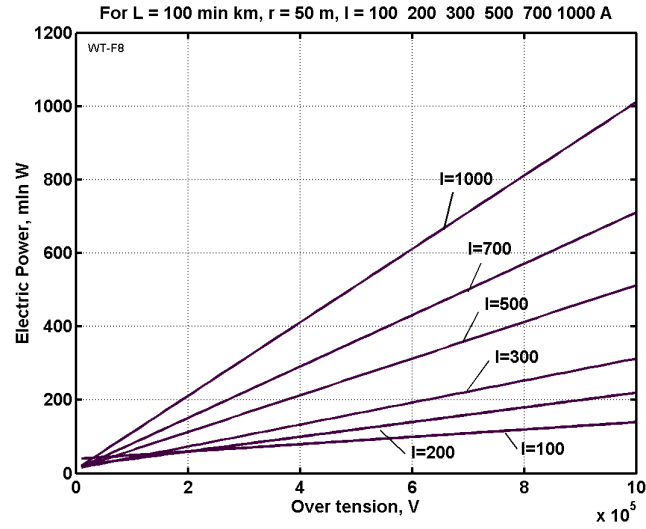
$$U_m = IR, \quad W_m = IU_m, \quad U = U_m + \Delta U, \quad W = IU, \quad \eta = 1 - W_m / W, \quad (5)$$

where  $U_m$ ,  $W_m$  are requested minimal voltage, [V], and power, [W], respectively;  $U$  is used voltage, V;  $\Delta U$  is electric voltage over minimum voltage, V;  $W$  is used electric power, W;  $\eta$  is coefficient efficiency of the electric line.

The computation of mentioned over values are presented in Figs. 11 ÷ 13. As you can see we can transfer the electric power of millions watts in outer space with very high efficiency, better than in Earth.

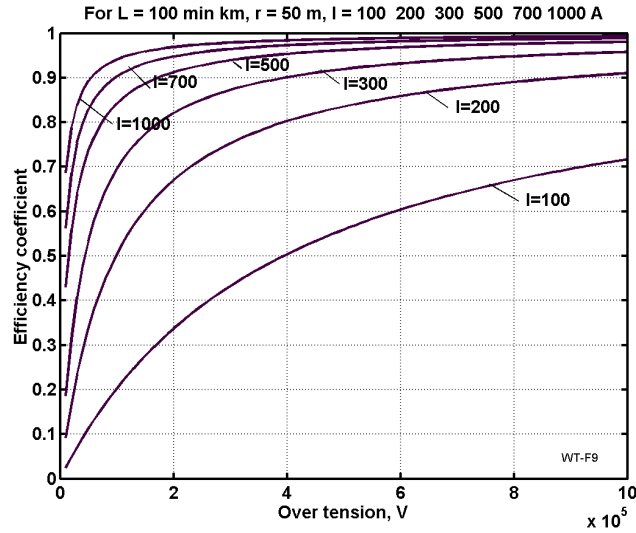


**Fig.11.** Requested minimum electric tension via the equilibrium plasma cable radius for different electric currency and for distance 100 millions kilometers.



**Fig.12.** Transferred electric power (millions W) via voltage over minimum electric tension (see requested minimum tension in Fig.10) for different electric currency, distance 100 millions of kilometers and radius of plasma cable 50 m.





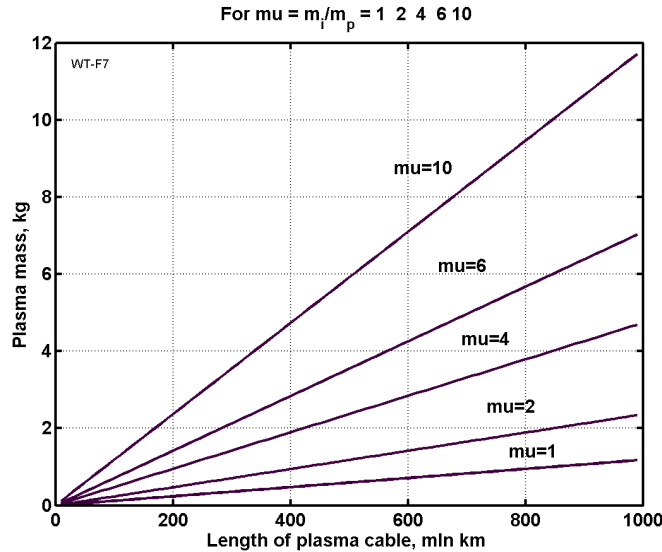
**Fig.13.** Coefficient efficiency of the electric transfer via over electric tension for different electric currency, distance 100 millions of kilometers and radius of plasma cable 50 m.

The equilibrium mass  $M$  [kg] of plasma cable is

$$M = l S n m_i, \quad S = \pi r^2 = 2.25 \times 10^{14} \pi / n, \quad M = 2.25 \times 10^{14} \pi \mu m_p l, \quad (6)$$

where  $m_i$  is ion mass of plasma, kg;  $\mu = m_i/m_p$  is relative mass of ion;  $m_p = 1.67 \times 10^{-27}$  is mass of proton, kg. Look your attention - the equilibrium mass of plasma cable does not depend from radius and density of plasma cable.

Computations are presented in Fig. 14. The double plasma cable for Jupiter (distance is 770 millions km) made from hydrogen  $H_2$  ( $\mu = 2$ ) has mass only 3 kg. That means the mass of plasma cable is closed to zero.



**Fig. 14.** Mass of plasma cable versus the cable length and a relative mass of ion.

**2. Circle plasma cable.** Take a small length  $dl$  of plasma circle and write the attractive magnetic force  $F_1$  and centrifugal mass force  $F_2$

$$F_1 = \frac{\mu_0 H^2}{2} s, \quad H = \frac{I}{2R}, \quad s = 2r dl, \quad F_2 = \frac{V^2 dM}{R}, \quad dM = \pi r^2 n m_i dl, \quad (7)$$

where  $R$  is radius of the plasma circle, m;  $V$  is circle rotation speed, m/s.

From equilibrium  $F_1 = F_2$  we have the request rotation speed  $V_R$  of plasma circle:

$$V_R^2 = \frac{\mu_0}{2\pi n_i} \frac{I^2}{rRn}, \quad (8)$$

For  $r = 15$  m;  $n = 10^{12}$ ;  $m_p = 1.67 \times 10^{-27}$  kg;  $R = 0.5 \times 10^{-11}$  m;  $I = 10$  A the request rotation velocity is 0.1 m/s.

**3. Electric pressure from the plasma cable.** The plasma has pressure in plasma cable. This pressure is small, but the cable can has a large diameter (up 200 m or more) and this pressure acting a long time can accelerate or brake the space apparatus. Electric pressure  $P$  can be computed by equations

$$P_m = \frac{\mu_0 H^2}{2}, \quad H = \frac{I}{2\pi r}, \quad P = 2P_m S = \frac{\mu_0}{4\pi} I^2, \quad (9)$$

*Estimation.* For  $I = 10^4$  A the electric pressure equals 10 N, for  $I = 10^5$  A one equals 1000 N. In reality the electric pressure may be significantly more because the kinetic pressure along cable axis may be more then plasma pressure into plasma cable (see below).

**4. Additional power from a space apparatus motion.** This power is

$$W = PV, \quad (10)$$

where  $V$  is apparatus speed, m/s.

*Estimation.* For  $V = 11$  km/s,  $I = 10^3$  A, this power equals 550 W, for  $I = 10^5$  the power equals 55000 W. We spend this power when space apparatus move off from the energy source and receive it when apparatus approach to the energy station.

**5. Track length of plasma electrons and ions.** The track length  $L$  and the track time  $\tau$  of particles is

$$L = v_T / \nu, \quad \tau = 1 / \nu, \quad (11)$$

where  $v_T$  is particle velocity, cm/s;  $\nu$  is particle collision rate, 1/s.

The electron and ion collision rate are respectively:

$$\begin{aligned} \nu_e &= 2.91 \times 10^{-5} n_e \ln \Lambda T_e^{-3/2} \text{ s}^{-1} \\ \nu_i &= 4.80 \times 10^{-8} Z^4 \mu^{-1/2} n_i \ln \Lambda T_i^{-3/2} \text{ s}^{-1}, \end{aligned} \quad (12)$$

where  $Z$  is ion charge state,  $\ln \Lambda \approx 5 \div 15 \approx 10$  is Coulomb logarithm,  $\mu = m_i/m_p$  is relative mass of ion;  $m_p = 1.67 \times 10^{-27}$  is mass of proton, kg;  $n$  is density of electrons and ions respectively;  $T$  is temperature of electron and ion respectively, eV.

Electron and ion terminal velocity are respectively:

$$\begin{aligned} v_{Te} &= (kT_e / m_e)^{1/2} = 4.19 \times 10^7 T_e^{1/2} \text{ cm/s} \\ v_{Ti} &= (kT_i / m_i)^{1/2} = 9.79 \times 10^7 \mu^{-1/2} T_i^{1/2} \text{ cm/s} \end{aligned} \quad (13)$$

Substitute equations (12)-(13) in (11) we receive

$$\begin{aligned} L_e &= 1.44 \times 10^{13} T_e^2 / n_e \ln \Lambda \text{ cm}, \\ L_i &= 2.04 \times 10^{13} T_e^2 / Z^4 n_e \ln \Lambda \text{ cm}, \end{aligned} \quad (14)$$

*Estimation.* For electron having  $n = 10^5$  1/cm<sup>3</sup>,  $T = 100$  eV,  $\ln \Lambda \approx 10$  we get  $L = 2 \times 10^6$  km,  $\tau \approx 300$  s. That means the plasma electrons have very few collisions, small dispersion, and it can have different average ELECTRON (relative ions) temperature along cable axis and perpendicular cable axis. It is not surprise because plasma can have different average temperature of electron and ions. That also means that our assumption about same terminal and currency electron velocities is very limited and parameters of plasma electric system will many better, then in our computation. The plasma in our system may be very cooled in radial direction and hot in axial direction. That decreases an electric currency needed for plasma compression and allows to transfer a plasma beam, energy, and thrust at long distance.

**6. Long distance wireless transfer of electricity in Earth.**

The transferring electric energy from one continent to other continent through ionosphere and Earth surface is described over. For this transferring we need two space towers of 100 km height, The towers must have a big conducting ball at top end and underground (better underwater) plates for decreasing the contact electric resistance. The contacting ball is large (up to 100 ÷ 200 m diameter) inflatable gas balloon having the conductivity layer (covering).

Let us to offer the method which allows computation the parameters and possibilities this electric line.

The electric resistance and other values for big conductivity medium can be estimated by equations:

$$R = \frac{U}{I} = \frac{1}{2\pi a\lambda}, \quad W = IU = 2\pi a\lambda U^2, \quad E_a = \frac{U}{2a}, \quad (15)$$

where  $R$  is electric resistance of big conductivity medium,  $\Omega$  (for sea water  $\rho = 0.3 \Omega\cdot\text{m}$ );  $a$  is radius of contacting balloon, m;  $\lambda$  is electric conductivity,  $(\Omega\cdot\text{m})^{-1}$ ;  $E_a$  is electric intensity on the balloon surface, V/m.

The conductivity  $\lambda$  of  $E$ -layer of Earth's ionosphere as the rare ionized gas can be estimated by equations:

$$\lambda = \frac{ne^2\tau}{m_e}, \quad \text{where } \tau = \frac{L}{v}, \quad L = \frac{kT_k}{\sqrt{2\pi} r_m^2 p}, \quad v^2 = \frac{8kT_k}{\pi m_e}, \quad (16)$$

where  $n = 3.1 \times 10^9 \div 5 \times 10^{11} \text{ 1/m}^3$  is density of free electrons in  $E$ -layer of Earth's ionosphere,  $1/\text{m}^3$ ;  $\tau$  is a track time of electrons, s;  $L$  is track length of electrons, m;  $v$  is average electron velocity, m/s;  $r_m = 3.7 \times 10^{-10}$  (for hydrogen  $\text{N}_2$ ) is diameter pf gas molecule, m;  $p = 3.2 \times 10^{-3} \text{ N/m}^2$  is gas pressure for altitude 100 km,  $\text{N/m}^2$ ;  $m_e = 9.11 \times 10^{-31}$  is mass of electrons, kg.

The transfer power and efficiency are

$$W = IU, \quad \eta = 1 - R_c / R, \quad (17)$$

where  $R_c$  is common electric resistance of conductivity medium,  $\Omega$ ;  $R$  is total resistance of the electric system,  $\Omega$ .

See the detail computations in Macro-Projects section.

**7. Earth's ionosphere as the gigantic storage of electric energy.** The Earth surface and Earth's ionosphere is gigantic spherical condenser. The electric capacitance and electric energy storied in this condenser can be estimated by equations:

$$C = \frac{4\pi\epsilon_0}{1/R_0 - 1/(R_0 + H)} \approx 4\pi\epsilon_0 \frac{R_0^2}{H}, \quad E = \frac{CU^2}{2}, \quad (18)$$

where  $C$  is capacity of condenser, C;  $R_0 = 6.369 \times 10^6 \text{ m}$  is radius of Earth;  $H$  is altitude of  $E$ -layer, m;  $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$  is electrostatic constant;  $E$  is electric energy, J.

The leakage currency is

$$i = \frac{3\pi\lambda_a R_0^2}{H} U, \quad \lambda_a = n_a e \mu, \quad R_a = \frac{H}{4\pi\lambda_a R_0^2}, \quad t = CR_a, \quad (19)$$

where  $i$  leakage currency, A;  $\lambda_a$  is conductivity of Earth atmosphere,  $(\Omega\cdot\text{m})^{-1}$ ,  $n_a$  is free electron density of atmosphere,  $1/\text{m}^3$ ;  $\mu = 1.3 \times 10^{-4}$  (for  $\text{N}_2$ ) is ion mobility,  $\text{m}^2/(\text{sV})$ ;  $R_a$  is Earth's atmosphere resistance,  $\Omega$ ;  $t$  is time of discharging in  $e = 2.73$  times, s;

**8. Magnetic Sail.** Circle plasma cable allows creating the gigantic Magnetic Sail. This sail has drag into Solar wind, which can be used as a thrust of a space ship. The electric resistance of plasma MagSail is small and MagSail can exist some years. That is also big good storage of electric energy. Space ship connects to MagSail by magnetic force.

The energy storage in plasma ring is

$$E_R = \frac{L_R I^2}{2}, \quad \text{where } L_R = \mu_0 \frac{\pi R}{2}, \quad (20)$$

where  $E_R$  is energy in magnetic ring, J [15];  $L_R$  is inductance of magnetic ring, H;  $R$  is radius of magnetic ring, m.

The ring spends power

$$U_m = R_m I, \quad W_m = IU_m, \quad (21)$$

The existing time is

$$\tau \approx c_R \frac{E_R}{W_m}, \quad (22)$$

where  $c_R$  is part of ring energy spent in life time, s ( $0 < c_R < 1$ ).

The ring energy is enough for some years of ring existing.

See the estimations in Projects section.

## Macroprojects

The macroprojects discussed below are not optimal. These are only examples of estimations: what parameters of system we can have.

### 1. Space electric line the length in 100 millions of km.

Let us take the following data of the electric line: radius of plasma cable is  $r = 150$  m, (cross-section of plasma cable equals  $S = \pi r^2 = 7.06 \times 10^4 \text{ m}^2$ ), plasma density is  $n = 10^{10} \text{ 1/m}^3$ , electric current is  $I = 100$  A, electric voltage is  $U = 2 \times 10^6$  V. Use the equations (1)-(6) we are receiving:

Electron velocity is  $u = I/enS = 8.85 \times 10^5$  m/s, electron temperature in eV is  $T = 2.23$  eV, electron temperature in K is  $T_k = 2.59 \times 10^4$  K, specific electric resistance is  $\rho = 3 \times 10^{-4} \Omega \cdot \text{m}$ , Coulomb logarithm is  $\ln \Lambda = 10$ , charge state is  $Z = 1$ , electric resistance is  $R = 2\rho L/S = 8.8 \times 10^2 \Omega$ , loss voltage is  $U_m = IR = 8.8 \times 10^4$  V, loss power is  $W_m = IU_m = 8.8 \times 10^6$  W, transfer power is  $W = IU = 2 \times 10^8$  W, coefficient efficiency is  $\eta = 0.956$ .

As you see, our system can transmit 200 million watts of power at distance 100 million kilometers with efficiency 95.6%. I remind that the distance to Mars is only about 60 million of kilometers.

Mass of our plasma line from hydrogen  $\text{H}_2$  is only 470 g.

### 2. Transferring electric energy to Moon or back.

Let us take the initial data: radius of plasma cable  $r = 15$  m ( $S = \pi r^2 = 706 \text{ m}^2$ ), plasma density  $n = 10^{12} \text{ 1/m}^3$ , electric current  $I = 1000$  A, distance 385,000 km.

Then:  $u = I/enS = 8.85 \times 10^6$  m/s,  $T = 223$  eV,  $T_k = 2.59 \times 10^6$  K,  $\rho = 3.1 \times 10^{-7} \Omega \cdot \text{m}$ ,  $\ln \Lambda = 10$ ,  $Z = 1$ ,  $R = 2\rho L/S = 3.4 \times 10^{-1} \Omega$ ,  $U_m = IR = 3.4 \times 10^2$  V,  $W_m = IU_m = 3.4 \times 10^5$  W.

If voltage is  $U = 3.4 \times 10^3$  V, then transmitting power is  $W = IU = 3.4 \times 10^8$  W, coefficient efficiency is  $\eta = 0.9$ .

If  $U = 3.4 \times 10^4$  V, then  $W = IU = 3.4 \times 10^8$  W,  $\eta = 0.99$ .

As you see, this system can transmit  $340 \div 3400$  million watts of power to Moon at distance 385,000 kilometers with efficiency  $90 \div 99\%$ .

If we take electric current  $I = 100$  A and voltage  $U = 3.4 \times 10^3$  V, then the transfer energy is  $W = IU = 3.4 \times 10^7$  W,  $\eta = 0.9$ . The same parameters are transfer energy to Earth's Space Station. Now the International Space Station has only electric power  $W = 10^4$  W.

**3. Transferring energy to Mars** located beyond the in Sun opposed on Earth side. In this case we use the circle plasma transfer (Fig. 5).

Let us take the following initial data: Radius of circle  $R = 1.9 \times 10^{11} \text{ m} = 190$  millions kilometers (Length of circle equals  $L \approx 12 \times 10^{11} \text{ m}$ ),  $r = 150$  m ( $S = \pi r^2 = 7.06 \times 10^4 \text{ m}^2$ ),  $n = 10^{10} \text{ 1/m}^3$ ,  $I = 100$  A,  $U = 10^7$  V.

Then:  $u = I/enS = 8.85 \times 10^5$  m/s,  $T = 2.23$  eV,  $T_k = 2.59 \times 10^4$  K,  $\rho = 3.1 \times 10^{-4} \Omega \cdot \text{m}$ ,  $\ln \Lambda = 10$ ,  $Z = 1$ ,  $R = \rho L/S = 5.27 \times 10^3 \Omega$ ,  $U_m = IR = 5.27 \times 10^5$  V,  $W_m = IU_m = 5.27 \times 10^7$  W,  $W = IU = 2 \times 10^8$  W,  $\eta \approx 0.95$ .

Mass of our plasma line from hydrogen  $\text{H}_2$  is only about 3 kg.

**4. Plasma Magnetic Sail** (Fig. 6). Let us take the following initial data: radius of MagSail  $R = 5 \times 10^4 \text{ m} = 50 \text{ km}$ ,  $r = 1.5 \times 10^3 \text{ m}$  ( $S = \pi r^2 = 7.06 \times 10^6 \text{ m}^2$ ),  $n = 10^8 \text{ 1/m}^3$ ,  $I = 10^4 \text{ A}$ .

Then:  $u = I/enS = 8.85 \times 10^7 \text{ m/s}$ ,  $T = 2.23 \times 10^4 \text{ eV}$ ,  $T_k = 2.59 \times 10^8 \text{ K}$ ,  $\rho = 3.1 \times 10^{-10} \Omega \cdot \text{m}$ ,  $\ln \Lambda = 10$ ,  $Z = 1$ ,  $R_m = \rho L/S = 1.38 \times 10^{-11} \Omega$ ,  $U_m = IR = 1.38 \times 10^{-7} \text{ V}$ ,  $W_m = IU_m = 1.4 \times 10^{-3} \text{ W}$ .

If  $U = 100 \text{ V}$ , the ring energy is  $E = 5 \times 10^6 \text{ J}$  [15]. If we spent only 10% of the ring energy, our MagSail will work about 10 years.

The gigantic plasma space MagSail is also an excellent storage of electric energy. If we take  $U = 10^5 \text{ V}$ , the ring will keep about  $E = 5 \times 10^9 \text{ J}$ .

**5. Wireless transferring energy between Earth's continents** (Fig. 7). Let us take the following initial data: Gas pressure at altitude 100 km is  $p = 3.2 \times 10^{-3} \text{ N/m}^2$ , temperature is 209 K, diameter nitrogen  $\text{N}_2$  molecule is  $3.7 \times 10^{-10} \text{ m}$ , the ion/electron density in ionosphere is  $n = 10^{10} \text{ 1/m}^3$ , radius of the conductivity inflatable balloon at top the space tower (mast) is  $a = 100 \text{ m}$  (contact area is  $S = 1.3 \times 10^5 \text{ m}^2$ ), specific electric resistance of a sea water is  $0.3 \Omega \cdot \text{m}$ , area of the contact sea plate is  $1.3 \times 10^3 \text{ m}^2$ .

The computation used equation (15)-(19) give: electron track in ionosphere is  $L = 1.5 \text{ m}$ , electron velocity  $v = 9 \times 10^4 \text{ m/s}$ , track time  $\tau = 1.67 \times 10^{-5} \text{ s}$ , specific resistance of ionosphere is  $\rho = 4.68 \times 10^{-3} (\Omega \cdot \text{m})^{-1}$ , contact resistance of top ball (balloon) is  $R_1 = 0.34 \Omega$ , contact resistance of the lower sea plates is  $R_2 = 4.8 \times 10^{-3} \Omega$ , electric intensity on ball surface is  $5 \times 10^4 \text{ V/m}$ .

If the voltage is  $U = 10^7 \text{ V}$ , total resistance of electric system is  $R = 100 \Omega$ , then electric currency is  $I = 10^5 \text{ A}$ , transferring power is  $W = IU = 10^{12} \text{ W}$ , coefficient efficiency is 99.66%. In practice we are not limited in transferring any energy in any Earth's point having the 100 km space mast and further transfer by ground-based electric lines in any geographical region of radius  $1000 \div 2000 \text{ km}$ .

**6. Earth's ionosphere as the storage electric energy.** It is using the equations (18)-(19) we find the Earth's-ionosphere capacity  $C = 4.5 \times 10^{-2} \text{ C}$ . If  $U = 10^8 \text{ V}$ , the storage energy is  $E = 0.5CU^2 = 2.25 \times 10^{14} \text{ J}$ . That is large energy.

Let us now estimate the leakage of current. Cosmic rays and Earth's radioactivity create  $1.5 \div 10.4$  ions every second in  $1 \text{ cm}^3$ . But they quickly recombine in neutral molecule and the ions concentration is small. We take the ion concentration of lower atmosphere  $n = 10^6 \text{ 1/m}^3$ . Then the specific conductivity of Earth's atmosphere is  $2.1 \times 10^{-17} (\Omega \cdot \text{m})^{-1}$ . The leakage currency is  $i = 10^{-7} \times U$ . The altitude of E-layer is 100 km. We take a thickness of atmosphere only 10 km. Then the conductivity of Earth's atmosphere is  $10^{-24} (\Omega \cdot \text{m})^{-1}$ , resistance is  $R_a = 10^{24} \Omega$ , the leakage time (decreasing of energy in  $e = 2.73$  times) is  $1.5 \times 10^5$  years.

As you can clearly see the Earth's ionosphere may become a gigantic storage site of electricity.

## Discussion

The offered ideas and innovations may create a jump in space and energy industries. Author has made initial base research that conclusively show the big industrial possibilities offered by the methods and installations proposed. Further research and testing are necessary. As that is in science, the obstacles can slow, even stop, applications of these revolutionary innovations. For example, the plasma cable may be unstable. The instability mega-problem of a plasma cable was found in tokamak R&D, but it is successfully solved at the present time. The same method (rotation of plasma cable) can be applied in our case.

## Summary

This new revolutionary idea - wireless transferring of electric energy in the hard vacuum of outer space is offered and researched. A rare plasma power cord as electric cable (wire) is used for it. It is shown that a certain minimal electric currency creates a compressed force that supports the plasma cable in the compacted form. Large amounts of energy can be transferred hundreds of millions of kilometers by this method. The requisite mass of plasma cable is merely hundreds of grams. It is computed that the

macroprojects: transferring of hundreds of kilowatts of energy to Earth's International Space Station, transfer energy to Moon or back, transferring energy to a spaceship at distance of hundreds of millions of kilometers, transfer energy to Mars when it is on the other side of the Sun wirelessly. The transfer of colossal energy from one continent to another continent (for example, Europe to USA and back), using the Earth's ionosphere as a gigantic storage of electric energy, using the plasma ring as huge MagSail for moving of spaceships. It is also shown that electric currency in plasma cord can accelerate or slow various kinds of outer space apparatus.

### **Acknowledgement**

The author wishes to acknowledge R.B. Cathcart for advice.

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